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DESIGN OF THE CHESAPEAKE BAY BRIDGE

by R. A. Gilmore, M. ASCE

STRUCTURAL DIVISION

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DESIGN OF THE CHESAPEAKE BAY BRIDGE

R. A. Gilmore,¹ M. ASCE

The Chesapeake Bay Bridge was opened to traffic on July 30, 1952, marking the culmination of a 45-year effort by various interests to provide a crossing giving more convenient transportation between Maryland's eastern and western shores. Early efforts were confined to a crossing at Millers Island—Tolchester, practically due east of Baltimore, which was economical because of the extensive use of land fill areas and relatively shallow mud and water depths (see Plate 1). In 1938, the War Department objected to the proximity of this site to Aberdeen Proving Grounds and, since distances between Baltimore and Washington to the various resorts and municipalities of the Del-mar-va peninsula indicated greater traffic travel economy via the Sandy Point site, the Millers Island—Tolchester site was abandoned.

The original permit plans submitted to the War Department during preparation of the 1938 report were for a straight crossing from Sandy Point to a point northeast of Stevensville which would have given the shortest crossing of the Bay. This would have placed the crossing in an area where ships maneuver while changing sailing courses at Sandy Point Light; and the Corps of Engineers, U.S. Army, determined that the bridge should be located approximately 1-1/2 miles south of Sandy Point Light. In order to comply with this requirement, maintain maximum economy by crossing normal to the sailing course and land on favorable terrain, the curve was placed in the bridge structure.

No innovations are involved in the design of the Chesapeake Bay Bridge. Longer and wider bridges have been built and longer and heavier units of the types selected in the design (see Plate 2). The superstructure consists of simple composite beams and girders, simple trusses, cantilever trusses, and suspension spans all supporting a reinforced concrete roadway slab. The substructure consists of trestle and framed bents, open cofferdam piers, and Potomac type piers. The Potomac type pier is so-called because it was first used in the construction of the Potomac River Bridge near Dahlgren Naval Proving Grounds in 1939. A complete description of this type of pier will be given by a later speaker. All substructure units are supported by piling.

The 1600' main span of the suspension bridge provides slightly better than the required 1500' horizontal clearance between fenders and the 186.5' vertical box clearance above mean high water (see Plate 3). The main towers are slightly below the 355' maximum dictated by a one-time proposed airport near the bridge site. The combination of these required clearances made it necessary to use thru stiffening trusses hung from the cable by brackets on the floor beams to secure economical cable sag ratio.

The only other thru structure is the three span cantilever which crosses the deepest waters at the site near the eastern shore and provides a box clearance 63' above mean high water and 690' horizontal (see Plate 4). This channel was required for tows bound between wharfrage points on the eastern shore or directly between the south and the Chesapeake and Delaware Canal.

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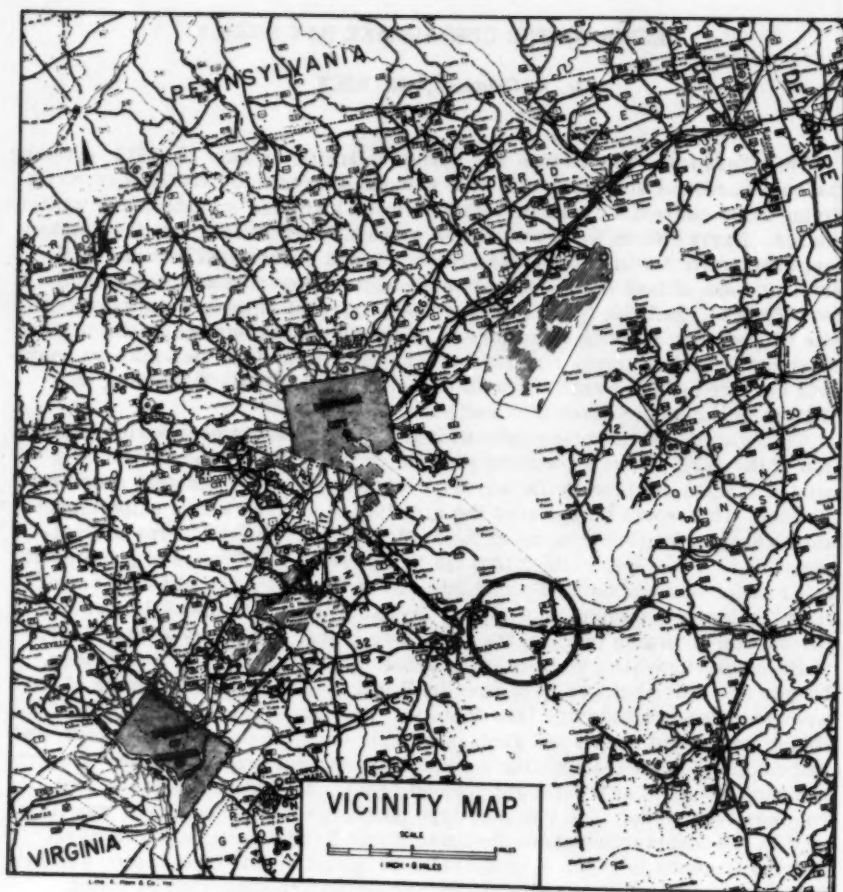


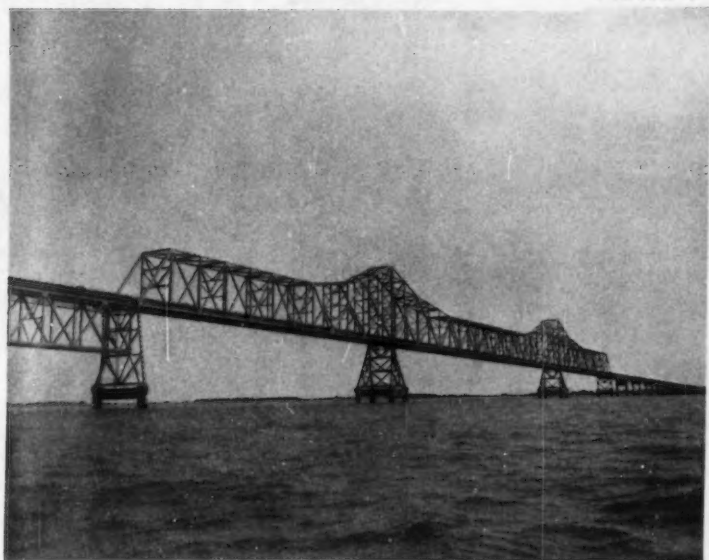
PLATE 1



PLATE 3



PLATE 4



Traffic-wise, the roadway is 28' between curbs, one 14' lane in each direction, narrow enough to discourage three-lane operation but wide enough to permit two-lane operation at reduced speeds past a disabled vehicle parked at the curb (see Plate 5). The vertical curve on the suspension spans provides passing sight distance at open highway speeds. The horizontal curve on the bridge is 1° - 40', approximately 3450' radius, and is superelevated 1/16" per foot. 1' - 6" reinforced concrete emergency walkways are provided on each side of the roadway, 6" above the roadway at the curb and bordered by 1' - 6" reinforced concrete parapets topped by a 2' high steel pipe railing. On the suspension spans, curbs, walkways, parapets, as well as railings, are structural steel and the curb height is increased to 9" to provide wider side slots for aerodynamic relief (see Plate 6).

All portions of the bridge are designed for the loadings of the American Association of State Highway Officials Standard Specifications for Highway Bridges dated 1949, the live load being H-20 S-16, except for the suspension spans where H-20 S-16 loading was used, for loaded length to and including 400' then decreased by straight linear ratio to H-15 S-12 for loaded lengths of 1600' and greater. Lateral and longitudinal forces are transferred to the substructure by positive devices, no reliance being placed on friction. Unit stresses were those of the A.A.S.H.O. Specifications, except for the suspension span cables and hangers and the steel piling. Cables were designed for 70,000 #/sq. in. maximum for dead load and 80,000 #/sq. in. maximum including other loads, hangers for 30,000 #/sq. in. maximum for dead load and 60,000 #/sq. in. maximum including other loads, and steel piling for 70 tons per pile maximum for dead and live loads and 130 tons per pile maximum including other loads. Test piling was loaded to 240 tons per pile. Ice load was 12,500 #/foot of pier width applied at high water. One 3' wide wind slot covered by open steel bridge deck grating is provided in the middle of each traffic lane of the suspension spans, also for aerodynamic relief. Curbs, parapets, and railings are designed for approximately 4 times the minimum requirements of the A.A.S.H.O. Specifications.

Water depths increase from the western shore to 15' at Bent 29, to 20' at Pier 10, the last of the western side small open cofferdam piers, to 55' at the center of the main span, to 88' at the thru cantilever spans, and then decrease to 20' at Pier 41, the first of the eastern side open cofferdam piers, to 12' at Bent 30, and to 5' at the bulkhead of the eastern shore causeway (see Plate 7). A deep mud layer 82' in thickness occurs where deepest water is encountered, resulting in a total depth of mud and water of 170'. Underlying the mud is very dense fine green sand which furnishes the support for the piling.

At the channel faces of anchorage Piers 23 and 28, the back stays are only about 20 feet above the water and it was required that islands be constructed at these points to keep a ship out of control from severing the cables and dumping the suspension spans into the main channel (see Plate 8). These islands are slag and rock faced with sand cores and extend 130' toward the channel from the faces of the piers at the water line. At this point, the cables have attained a height of approximately 75' and only the comparatively flimsy superstructure of a ship might collide with the cables. The strut between them was placed to make them react in unison in the event of such a collision and the combined strength of the cables is such that the superstructure would be swept from the ship.

To secure firm foundations for the islands, it was necessary to remove the mud and silt down to clean sand (see Plate 7). This involved only 20 feet of unsuitable materials at Pier 23 but, at Pier 28, up to 70 feet of mud and silt had

PLATE 5



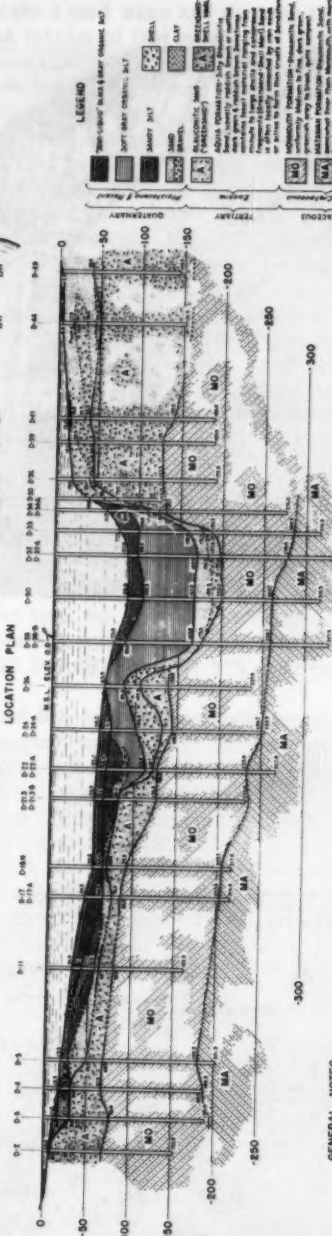
PLATE 6





CHESAPEAKE BAY

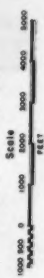
KENT ISLAND
QUEEN ANNE'S COUNTY



LEGEND



GEOLOGIC SECTION



GENERAL NOTES

1. TEST BORINGS by Regional Geologic Map (see Section 1)
2. GEOLOGIC INFORMATION by J.C. Grier, Jr. based on
3. 100' of boring samples
4. 100' of boring samples
5. 100' of boring samples
6. 100' of boring samples
7. 100' of boring samples
8. 100' of boring samples
9. 100' of boring samples
10. 100' of boring samples

STATE OF MARYLAND STATE BOARD OF CONSERVATION CHESAPEAKE BRIDGE CHESAPEAKE BRIDGE	
DATE: 11-15-1958	BY: J.C. Grier, Jr.
SCALE: 1" = 100'	PROJECT: CHESAPEAKE BRIDGE
C-508-	

PLATE 8

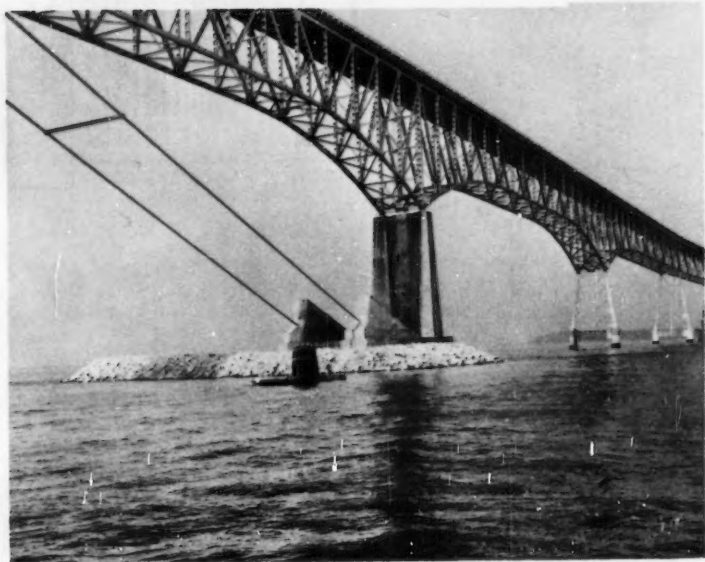
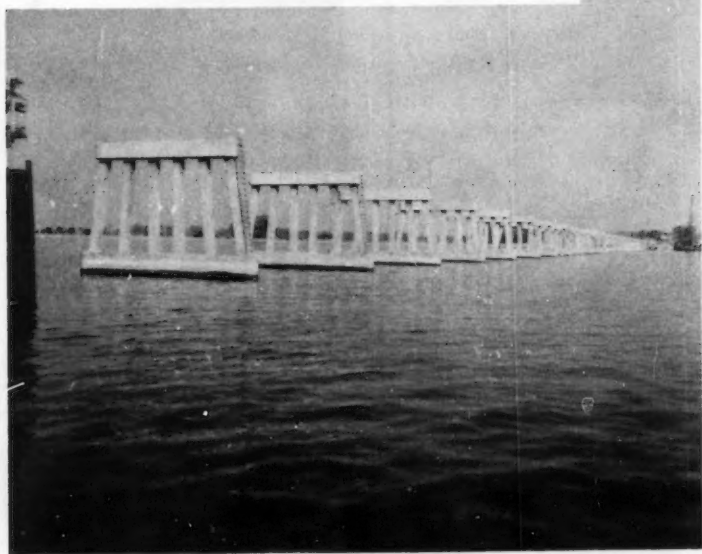


PLATE 9



to be removed necessitating silt removal also at Pier 27 so that the surcharge from the islands would not create a mud wave and destroy the pier. Island construction was completed the middle of last month and brings to a close all construction operations in connection with the Chesapeake Bay Bridge.

Alternate designs were made for the bents and all piers, except Piers 11 to 22, inclusive, and 29 to 40, inclusive. These excepted piers are all Potomac type which was believed to be the most economical for the design conditions.

Bents 1 to 65 were designed as trestle bents using either steel or cast-in-place concrete piling or as rigid frame concrete bents supported on steel H-piles. The low bid for the western shore bents, numbers 1 to 29, inclusive, was for the trestle type using monotube cast-in-place piles (see Plate 9). The low bid for the eastern shore bents, numbers 30 to 65, inclusive, was for the reinforced concrete rigid frame bents supported on steel piling (see Plate 10). Bidding indicated less than 2% difference in the alternate bent designs.

Piers 1 to 10, west of the channel span, and 41 to 57, east of the channel span, were designed both as open cofferdam type and as Potomac type (see Plate 11 West Side and Plate 12 East Side). The low bid in each case was for open cofferdam type in the relatively shallow water at their locations; however, here, again, the bidding indicated less than 2% difference in the alternate designs.

Anchorage Piers 23 and 28 were designed as reinforced concrete open caissons and as open cofferdam piers on piling. Piers 24, 25, 26, and 27, which support the main towers and side towers of the suspension spans, were designed as reinforced concrete open caissons and as Potomac type piers (see Plate 13). The low bids received were for open cofferdam anchorages on piling for Piers 23 and 28 and Potomac type for Piers 24 to 27, inclusive, and bidding indicated that these designs, together with the smaller islands resulting from their use, effected a saving of \$3,500,000 or about 35% over the reinforced concrete caissons.

Lightweight concrete was used for the roadway slabs for all girder, truss, and suspension spans. This concrete weighed approximately 105 pounds per cubic foot which reduced by approximately 1/3 the usual concrete deck dead weight. Because of the higher percentage absorption of lightweight concrete, the bottoms of all slabs are dampproofed. A one course 2" asphaltic concrete wearing surface was used on the roadway deck between curbs.

Ordinary concrete was used for the curbs, walkways, and parapets because these must remain uncoated for appearance and function and ordinary concrete as poured is more durable than lightweight. Ordinary concrete was also used for the roadway slabs of the 60' beam spans, since no economy could be effected by the use of lightweight concrete.

Minimum cover for the reinforcing steel in the bottom of the roadway slabs is 1-1/2" for the relatively low decks of the beam spans, 1-1/4" for the girder spans, and 1" for all truss and suspension spans.

The bridge was constructed using funds derived from the sale of revenue bonds. In this type of financing, revenues derived from toll collection are the sole monies pledged for construction, maintenance, operation, and debt service. The State owns the bridge but its credit, i.e., taxing power, is specifically not pledged. The bridge is not mortgaged, the bondholders bought the bonds under a trust agreement which provides that the State will levy tolls for such period, not in excess of thirty years, as may be necessary to enable the Commission to repay the loan with interest at the stipulated rate. Revenues to date are approximately double prefinancing estimates.

Construction funds available from the sale of bonds, premium on the bonds,

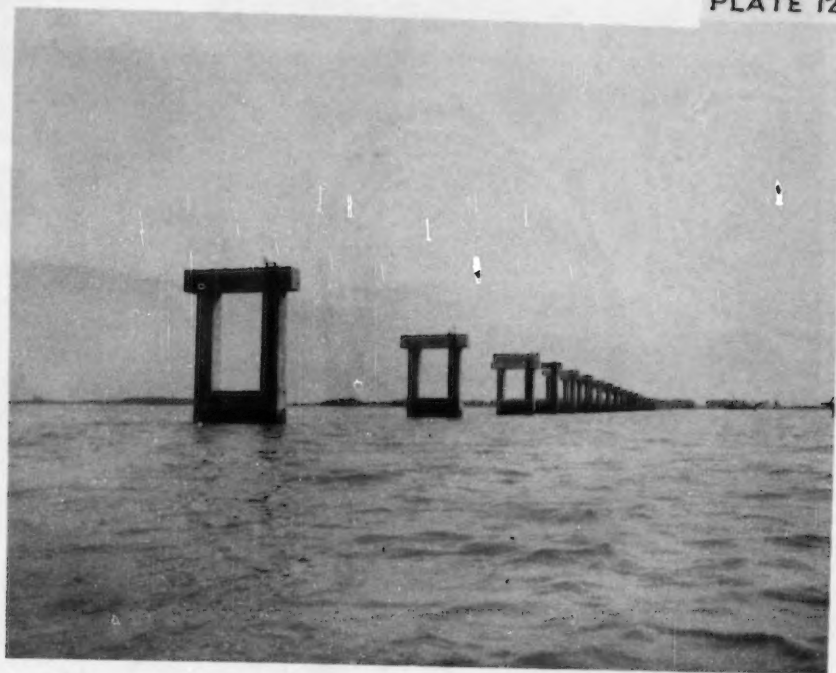
PLATE 10

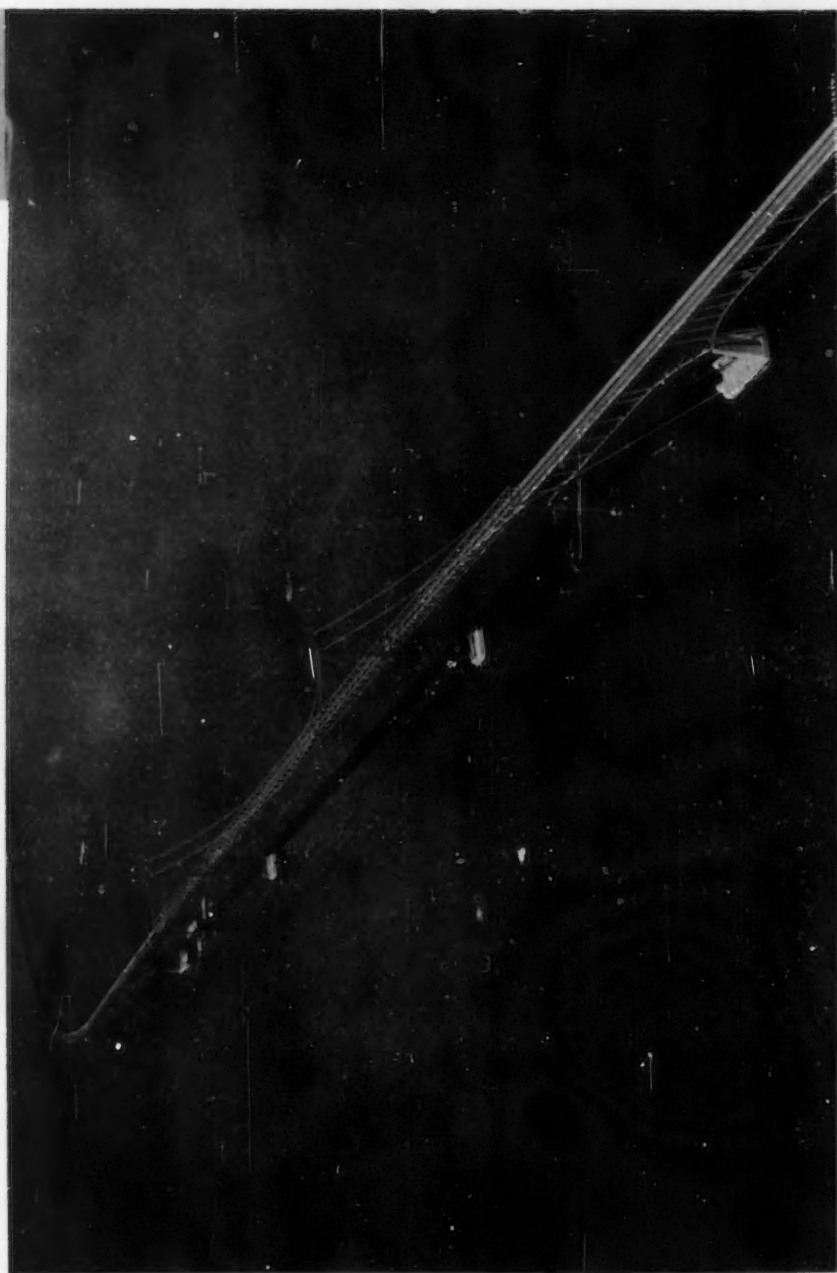


PLATE 11



PLATE 12





and interest on the unexpended portion of the construction fund during construction totalled approximately \$45,200,000.

Preliminary expenses amounted to \$530,000 and include the costs of engineering and traffic surveys and reports, borings, driving and loading test piles, soils laboratory investigations, legal fees, printing and other costs in connection with the issuance of bonds and similar items; lands and rights-of-way amounted to \$92,000; shore approach roadways and the eastern shore causeway, \$2,550,000; substructure and islands, \$21,338,000, approximately \$19,000,000 of which is below the surface of the water; superstructure, including aids to air and water traffic, \$16,775,000; the administration building, toll booths, toll collection equipment, maintenance and operation equipment, office furniture, etc., \$554,000; legal and administrative expenses, engineering, surveys, and other costs, \$3,077,000, combined, these costs total \$44,916,000.

Consulting engineers associated with J. E. Greiner Company in the design of the bridge were Moran, Proctor, Freeman and Muesser; Dexter R. Smith; George S. Richardson; Harry A. Balke; Brookhart and Tyo; and Frankland and Leinhard. Architect and landscape architect were Charles H. Marshall, Zink and Craycroft, and R. Brooke Maxwell and Associates, respectively.

Principal contractors for the work were J. Rich Steers, Inc.; Bethlehem Steel Company; Frederick Snare Corporation; Merritt-Chapman and Scott Corporation; Booth and Flinn Company; Baltimore Contractors, Inc.; C. J. Langenfelder & Sons.; Taller & Cooper, Inc.; Nello L. Teer Company; Construction Aggregates Corporation; Blumenthal-Kahn Electric Co., Inc.; Millison Construction Co., Inc.; and the John D. Sheetz Construction Co.

The cooperation and know-how of these engineers and contractors enabled the State of Maryland to acquire a substantial and impressive structure in timely fashion (shown by moonlight on Plate 14). Properly administered, operated, and maintained, it promises many years of faithful and effective service to the people of Maryland and their neighbors in the other states of the eastern seaboard.

PLATE 14

